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Effect of irrigation levels on the production of *Arachis hypogeaea* L.

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Abstract

Peanuts (*Arachis hypogaea L.*) are a high-protein alternative for making up for nutritional deficiencies. Adequate irrigation management is essential for greater productivity of this crop, especially in Brazilian Cerrado. In this context, this study aimed to evaluate the productive characteristics of peanuts subjected to different irrigation levels under controlled conditions. The research was conducted in the Savannah region at the Federal University of Rondonópolis, in Rondonópolis - Mato Grosso, Brazil. The soil used to grow the peanuts was Oxisol. The experimental design was completely randomized with five treatments (50%, 75%, 100%, 125%, and submerging at 150% of field capacity) and five replications. The analyzed variables included the number of pods, number of grains per pod, pod dry mass, and dry mass of grains. The number of pods and the number of grains per pot fitted the increasing linear model as a function of different levels of field capacity. On the other hand, the pod dry mass and dry mass of grains per pod showed a quadratic regression behavior. Different levels of field capacity had a significant impact on peanut productivity. The treatment with 100% of field capacity yielded the best results in terms of peanut productivity and grain quality.

Keywords: Peanut; deficit irrigation; water stress; peanut yield; irrigation management.
Abbreviations: CEC_*Cations* Exchange Capacity, ETc_Evapotranspiration, kPa_Kilopascal, m_Aluminum saturation, OM_Organic matter, V_Base saturation.

Introduction

The peanut (Arachis hypogaea L.) is a dicotyledonous crop belonging to the Leguminosae family, originating in South America. It is known for its high protein content, caloric value, and vitamin richness. It ranks as the fourth most cultivated oilseed in the world and is currently planted on a large scale in the Americas, Africa, and Asia (Landau et., 2020). Consequently, this oilseed holds significant importance worldwide, as the demand for protein-rich foods remains high due to the limited consumption of animal-based products, which are often inaccessible to a large portion of the population given their high costs (Camargo et al., 2011).
The estimated peanut grain production area in Brazil for the 2022/2023 crop season is 220.9 thousand hectares, with a total productivity of 4.041 kg per hectare, marking an 8.3% increase compared to the previous 2021/2022 crop season. Additionally, the overall peanut production for the 2022/2023 season reached 892.7%, representing a 19.6% increase compared to the 2021/2022 crop season, according to data from CONAB (2023). Peanut is a plant sensitive to water stress, and its response can vary depending on the developmental stage. Water deficit during the vegetative period of peanuts leads to an elongated growth cycle, resulting in higher cultural care expenses (Dias et al., 2019).
Irrigation management significantly influences peanut development as water stress can affect the productive characteristics and overall growth of the crop (França et al., 2021; Zurweller et al., 2021). Today, competition for water supply has intensified among farmers (Mahdavi et al., 2021). Therefore, it is crucial to conduct studies that determine appropriate irrigation levels that increase peanut yield.
Considering the significance of peanut production and its impact on supporting the population, further research is required to explore the appropriate use of water and enhance peanut productivity, thereby contributing to achieving Goal 2 (Zero Hunger) and Goal 12 (Sustainable consumption and production) among the United Nations Organization's seventeen Sustainable Development Goals (SDGs). In this context, the objective of this study is to evaluate the productive characteristics of peanuts (*Arachis hypogaea L.*) subjected to different irrigation levels.

Results and Discussion

Number of pods

The number of pods per pot was significant ($p < 0.05$) presented a positive linear relationship, with the highest number of pods per pot achieved at the maximum field capacity of 150%, representing an 83.34% increase (Figure 1). Interestingly, peanuts demonstrated the ability to produce even under waterlogging conditions, as the treatment with 150% of field capacity (submerging treatment) resulted in 60.52 pods pot^{-1}. Conversely, under water stress conditions,

the number of pods achieved its minimum values, with approximately 13 and 20 pods per pot observed in the treatments with 50% and 75% of field capacity, respectively.
These findings align with França et al. (2021), who reported reduced pod production in peanuts under water stress conditions, resulting in a 30% decrease compared to treatments without water stress. Dehkordi (2020) also investigated the effect of irrigation on peanut productivity and observed that irrigation management significantly influenced crop yield, with the highest yields found in treatments receiving 60 mm cumulative pan evaporation and 135% of ETc.

Number of grains
The number of grains per pot was significant ($p < 0.05$) demonstrated a positive linear relationship, with an 82.21% increase (Figure 2). The highest number of grains per pot was observed at the 150% field capacity (approximately 86.52 grains pot^{-1}), while the lowest number of grains occurred in the treatment with 50% of field capacity (approximately 15.4 grains pot^{-1}).
However, despite the 150% treatment resulting in higher grain production per pot, the grains displayed poor quality, with a deformed appearance due to excess water (Figure 3). The 100% treatment exhibited grains of better quality, i.e., larger and without deformations (Figure 3). Similarly, under waterlogging conditions, the grains from the treatments with water deficit (50% field capacity) were smaller and showed minor deformations.
Rathore et al. (2021) observed in their studies with different irrigation levels in peanut cultivation that total irrigation (100% of evapotranspiration) increased grain and pod yield compared to other treatments with water deficit, showing a decrease in yield and growth when the plant was subjected to water stress.
Boydak et al. (2021) also investigated peanut productivity under different irrigation levels and found that water deficit reduced peanut yield, with higher seed production observed in treatments with 100% and 75% of evapotranspiration.

Pod dry mass
The pod dry mass was significant ($p < 0.05$) fitted to a quadratic regression model with an 27.83% increase (Figure 4), the highest mass at a field capacity of 179.625% (9.450 g pot^{-1}). Under water stress conditions, the treatment with 50% of field capacity resulted in the lowest pod dry mass (2.86 g pot^{-1}). Silva et al. (1998) also observed a quadratic effect on peanut productivity concerning irrigation levels in their studies on the effect of irrigation management on peanut production quality.
A study with peanuts subjected to water stress noticed that the peanut shell fraction and the number of pods increased with the reduction of irrigation, in which higher yields of peanut shells and pods were observed with 80% of evapotranspiration (Rathore et al., 2021). These findings differ from those in this study, where higher pod dry masses were found under flooded conditions (Figure 4).

Dry mass of grains
In terms of the dry mass of grains (g) per pot was significant ($p < 0.05$) a quadratic regression behavior was also observed with an 46.21% increase (Figure 5), with the highest mass obtained at a field capacity of 108.20% (25.60 g pot^{-1}). The treatments with water deficit (50%) and waterlogging (150%)

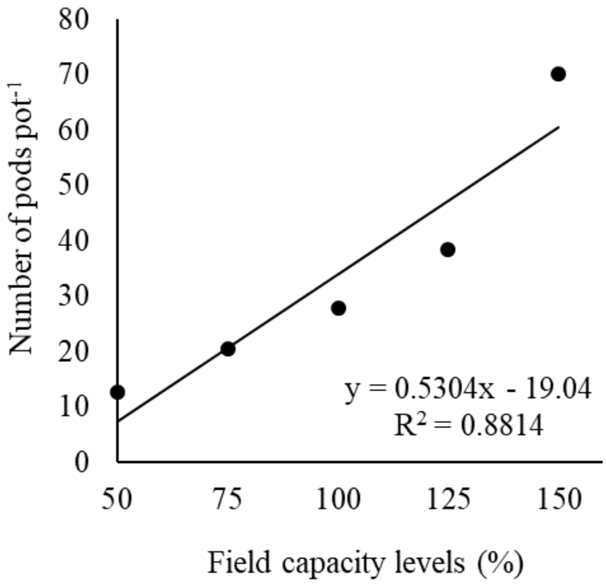

Fig 1. Number of pods per pot as a function of different levels of field capacity (%).

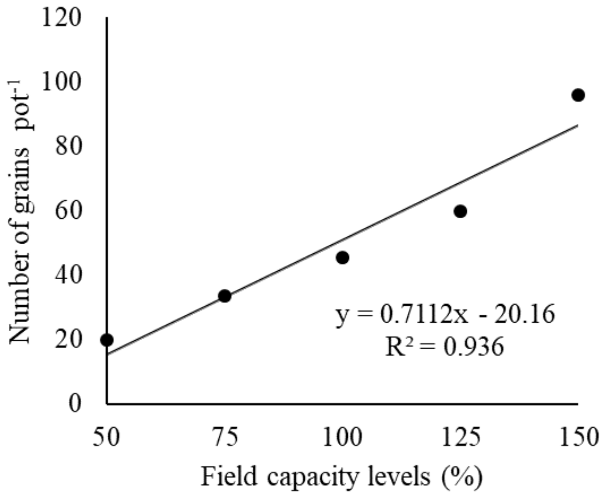

Fig 2. Number of grains per pot as a function of different levels of field capacity (%).

showed the lowest values of the dry mass of grains, 6.38 g pot^{-1} and 12.4 g pot^{-1}, respectively.
These findings are consistent with Prado et al. (2021), who reported a quadratic effect of irrigation levels on peanut productivity, with the highest yields observed at irrigation levels between 100% and 126% of field capacity. França et al. (2021) also observed a positive linear relationship in their research on irrigation levels in peanut cultivation, with the highest grain masses found in treatments with 100% replenishment of crop evapotranspiration and lower masses observed in treatments with water deficit.
Overall, these results highlight the importance of proper irrigation management for peanut production. While waterlogging conditions (150% field capacity) led to increased pods productivity (Figure 1), the grain quality was poor due to excess water (Figure 3). On the other hand, water stress conditions resulted in reduced grain production and quality, as observed across all variables in this study. Despite peanuts being a robust plant, adequate irrigation is necessary for optimal development, with the 100% field capacity treatment yielding the best results.

Fig 3. Pods according to their respective treatment of field capacity levels (%).

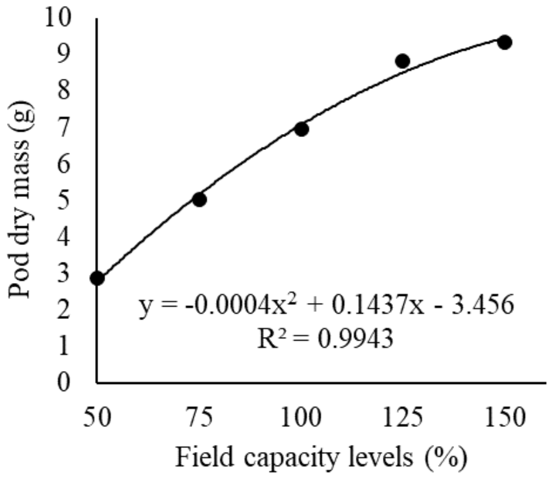

Fig 4. Pod dry mass (g) as a function of different levels of field capacity (%).

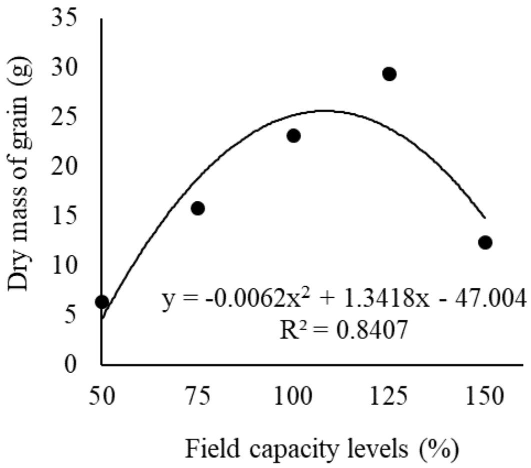

Fig 5. Dry mass of grains (g) as a function of different levels of field capacity (%).

Materials and Methods

Study area and condition

The research was conducted in the year 2021 at the Federal University of Rondonópolis, MT, Brazil with the geographic coordinates were 16° 28' South Latitude and 50° 34' West Longitude, at an altitude of 284 m. The climate of the region is characterized by a rainy summer and a dry winter, classified as Aw according to the Köppen's classification and a mean photoperiod of 11 hours and 39 minutes. The greenhouse where the experiment was conducted has an arched metal structure, with height of 3.05 m, width of 6.60 m, length of 18.05 m, cover and sides closed with transparent diffuser plastic film (75% transparency) and an evaporative cooling system Pad and Fan, which was programmed to maintain the temperature at 26 ±1 ºC and relative air humidity at 65% throughout the experimental period.

The soil was collected from a Brazilian Cerrado region at a depth of 0 - 20 cm, then sieved through a 2 mm mesh for chemical characterization (Table 1) and a 4 mm mesh for composing experimental units. The soil was classified as Oxisol (Embrapa, 2013). Each experimental plot consisted of three plants in a pot with a 6 dm^3 capacity. The peanut cultivar used for the experiment was the IAC - OL - 3.

Treatments and experimental design

The experimental design was completely randomized, with five treatments (50%, 75%, 100% (Control), 125%, and 150% of field capacity) and five replications, totaling 25 experimental units. Fertilization was carried out according to the nutritional requirements of peanut crops following Embrapa's recommendations (2008).

Conduction of study

Irrigation was monitored using five tensiometers, one for each treatment. Irrigation was performed when the soil reached a matric potential of 5 kPa, not exceeding 15 kPa, with reference to the treatment at 100% of field capacity. Initially, during the sowing phase, the same volume of water was applied to all experimental units until peanut emergence. Afterward, irrigation was initiated based on the respective treatments.

The soil moisture obtained by the tensiometers was determined using the soil water retention curve already obtained in the hydraulics laboratory of the Federal University of Rondonópolis. The soil water retention data in volume percentage was adjusted to the Van Genuchten equation using the Soil Water Retention Curve software.

To calculate soil moisture, the average soil water tension obtained from a digital tensiometer was used in conjunction with the soil water characteristic curve. Considering the soil moisture at field conditions and the volume of soil present in the pot, the amount of water needed to bring the soil back to field capacity was estimated. Irrigation was carried out directly and manually using a graduated cylinder.

The reference treatment (100% of field capacity) was initially irrigated at a tension of 15 kPa. The soil retention curve was estimated using a computer program, based on data obtained from the relationship between retained soil moisture and the

Table 1. Chemical and particle-size characterization of Oxisol collected in the 0-0.20 m layer in an area under Cerrado vegetation, Rondonópolis – Mato Grosso, Brazil.

pH	P	K	S	Ca	Mg	Al	H+Al	CEC	SB	V	m
$CaCl_2$	.... mg dm^{-3}			.... $cmol_c$ dm^{-3}						.... %	
4.4	1.3	18	2	0.5	0.2	0.6	4.8	5.6	0.8	13.5	44.4
Zn	Mn	Cu	Fe	B	OM	Clay	Silt	Sand			
.... mg dm^{-3}						.... g kg^{-1}					
0.7	21.8	0.2	64	0.15	21.3	455	100	445			

pressure exerted by the Richards membrane in the laboratory.

The analyzed productive variables were the number of pods, the number of grains per pot counted manually, and the pod dry mass and grains dried in a closed-circulation oven at 65°C until reaching a constant weight, after approximately 72 hours.

Statistical analysis

The data were subjected to analysis of variance at a 5% probability level using regression analysis with the SISVAR statistical software (Ferreira, 2019).

Conclusion

The productivity of peanuts is significantly influenced by field capacity levels. The treatment with 108.2% of field capacity yielded the best results in terms of peanut productivity and grain quality, producing the highest mass at 25.60 g pot^{-1}. Under water stress conditions, the treatment with 150% of field capacity (submerged) showed the poorest grain quality and the highest pod count, while the treatment with 50% of field capacity resulted in the lowest dry mass of pods at 2.86 g pot^{-1}. In the future, field studies can be conducted using peanut crops in conjunction with tensiometers to enhance research.

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